Section 4
Results of Compost-Amended Soil Tests (Task 2)

All of the compost-amended site test water quality data are presented in Appendix G, while Appendix H includes the flow measurements and mass discharge data. This section contains the results of various data evaluation efforts.

Soil and Compost Analysis

The terminology used in industry and science for compost and soil properties is somewhat inconsistent. In this report, percent by weight uses an oven-dried basis for calculation. Volumes can change depending on handling, storage, moisture content and other factors. Also, the density (weight per unit volume) of compost is usually much lower, 0.2 to 0.3 g/cm^3, than that of soil, 1.0 to 1.4 g/cm^3. A weight percent change from compost amendment is usually much lower than a volume unit change, and moisture capacity based on volume may be much different than moisture capacity based on weight.

The total C, total N, bulk density, particle density, gravimetric-water-holding capacity (field capacity) moisture, volumetric-water-holding-capacity (field capacity) moisture, total porosity, particle-size analysis, and soil structure of soil and soil/compost mixtures is given in Table 4-1. Results show large changes in the chemical and physical properties of the soil/compost mixtures due to the compost amendment.

Total C and organic matter was enhanced by adding compost, increasing from 0.1 to 0.4% C to about 1.1 to 5.2% C by weight. Total N was also enhanced, increasing from 0.02 to 0.08% to about 0.06 to 0.35% with the compost amendment. Gravimetric-field-moisture capacity increased significantly from 24% to 35% with the compost amendment. Volumetric-field-moisture capacity was also increased from 46 to 50% by the addition of compost.

Total porosity was increased from 41 to 48%. Bulk density was decreased from about 1.7 to 1.1 g/cm^3. Particle density was decreased from about 2.5 to 2.1 g/cm^3. Particle size analysis was not greatly affected by the compost amendment. Soil structure, which is not a quantitative property, was also not greatly affected by compost amendment.

Thus, there was a generally beneficial effect of the compost amendment in regards to nutrient content as well as soil physical properties known to affect water relations in soils.

Water Quantity Observations at Test Plots

This study utilized a dual tipping bucket system to measure surface runoff and subsurface flows versus time. As pointed out earlier, the tipping buckets did not accurately record all surface runoff or subsurface seepage at the test sites due to unexpected leakage or faulty operation of the tipping buckets. However, most of the surface runoff and subsurface flow information was obtained.

Table 4-1. Analysis of chemical and physical properties of soil-only and soil-compost treatments

Site	treatment	sample #	total C	total N	Field Capacity g/g	Field Capacity ml/ml	Total Porosity	Bulk Density	Particle Density
			%	%	%	%	%	g/cm^3	g/cm^3
CUH plot 1	no-compost	1	0.23	0.02	25	39	33	1.55	2.33
CUH plot 2	compost	1	3.14	0.20	38	41	46	1.08	1.99
CUH plot 5	no-compost	1	0.11	0.05	29	41	41	1.42	2.42
CUH plot 6	compost	1	1.15	0.06	35	36	48	1.03	1.97
Timbercrest	compost	1	5.23	0.35	45	50	48	1.10	2.10
Timbercrest	no-compost	1	0.34	0.08	28	46	35	1.65	2.54
Woodmoor	no-compost	1	0.42	0.04	24	37	36	1.54	2.42
Woodmoor	compost	1	3.56	0.22	42	43	45	1.03	1.87
CUH plot 1	no-compost	2	0.26	0.02	21	44	30	1.74	1.95
CUH plot 2	compost	2	3.24	0.22	31	46	50	1.17	2.07
CUH plot 5	no-compost	2	0.12	0.04	32	33	48	1.30	2.03
CUH plot 6	compost	2	1.02	0.07	37	39	57	.93	2.05
Timbercrest	no-compost	2	0.30	0.06	31	53	35	1.83	3.03
Timbercrest	compost	2	5.48	0.33	54	44	43	1.20	1.91
Woodmoor	no-compost	2	0.36	0.04	27	35	35	1.23	2.85
Woodmoor	compost	2	4.23	0.21	41	45	37	0.84	1.87

Site	treatment	sample #	Particle Size Analysis < 2mm parts percentage				soil structure by visual and feel method
			2-0.02	0.02-0.005	0.005-0.002	<.002	
			%	%	%	%	
CUH plot 1	no-compost	1	85	10	3	2	single grain / weak granular
CUH plot 2	compost	1	82	13	4	1	single grain / weak granular
CUH plot 5	no-compost	1	80	13	5	2	single grain / weak granular
CUH plot 6	compost	1	79	14	4	3	single grain / weak granular
Timbercrest	no-compost	1	75	19	4	2	single grain / weak granular
Timbercrest	compost	1	82	13	4	1	single grain / weak granular
Woodmoor	no-compost	1	77	14	5	4	single grain / weak granular
Woodmoor	compost	1	78	17	3	2	single grain / weak granular
CUH plot 1	no-compost	2	85	10	3	2	single grain / weak granular
CUH plot 2	compost	2	84	10	5	1	single grain / weak granular
CUH plot 5	no-compost	2	79	13	6	2	single grain / weak granular
CUH plot 6	compost	2	79	15	3	3	single grain / weak granular
Timbercrest	no-compost	2	75	18	5	2	single grain / weak granular
Timbercrest	compost	2	80	14	5	1	single grain / weak granular
Woodmoor	no-compost	2	78	13	4	4	single grain / weak granular
Woodmoor	compost	2	81	14	4	2	single grain / weak granular

Infiltration rate measurements were also made at the test plots using the ASTM D3385-94 double ring method. Table 4-2 shows the results of these tests, contrasting the measured infiltration rates at the compost-amended test plots with the rates measured at the test plots that only contained soil. The use of compost-amended soil resulted in significantly increased infiltration rates compared to soil alone. The infiltration rate increased from 1.5 to 10 times the untreated rates and should substantially decrease the runoff volumes and flow rates from turf areas during rain storms. These lower runoff volumes and flow rates would decrease many detrimental stormwater effects, including reduced mass discharges of pollutants, reduced downstream flooding, and improved in-stream habitat conditions for aquatic life. The additional infiltrating water would release more slowly to the surface waters after the initial runoff flows subsided, or would recharge deeper groundwaters, depending on subsurface soil conditions. The soil structure at the Alderwood soil sites would likely prevent much of this increased infiltrating water from reaching deeper groundwaters, but the compost amendments would still improve surface water flow characteristics, as extensively evaluated by Harrison *et al*. (1997) during the initial tests at the CUH test plots. Even though temperature was not monitored during this study, landscaped areas are an important moderating factor in controlling elevated runoff temperatures of urban stormwater. A healthier turf stand should also provide lower temperature runoff than bare soil, or a poor turf stand.

Table 4-2. Infiltration rate measurements at field test plots

Location	Test Plot Treatment	Average Infiltration Rate (cm/hr) (in/hr)	Improvement with Compost (ratio)
CUH plot 1	Alderwood soil A	1.2 (0.5)	
CUH plot 2	Alderwood soil A with Cedar Grove compost	7.5 (3.0)	6.3
CUH plot 5	Alderwood soil B	0.8 (0.3)	
CUH plot 6	Alderwood soil B with GroCo compost	8.4 (3.3)	10.5
Timbercrest	Alderwood soil C	0.7 (0.3)	
Timbercrest	Alderwood soil C with Cedar Grove compost	2.3 (0.9)	3.3
Woodmoor	Alderwood soil D	2.1 (0.8)	
Woodmoor	Alderwood soil D with Cedar Grove compost	3.4 (1.3)	1.5

As noted above, surface runoff and subsurface flows were monitored over several extended periods at the test plot sites. Table 4-3 summarizes the surface runoff and subsurface flow data from the complete set of flow data presented in Appendix G. This table shows the fractions of the total rainfall that resulted in surface runoff, subsurface flow, and other losses (assumed to be mostly evapotranspiration). The surface runoff fraction is the volumetric runoff coefficient (Rv) and is the simple ratio of runoff depth to rainfall depth. The four soil-only Alderwood test plots were quite different, with average Rv values ranging from about 0.01 to 0.25, reflecting a large amount of variability of infiltration conditions for this soil type. The age of construction of the test plots does not explain this variation.

The soil-only and compost-amended-soil test plots at the CUH site were quite similar, with both test plots in each pair having very similar Rv values (even though the infiltration measurements reported previously indicated large differences). In contrast, the newer test plots at Timbercrest and Woodmoor showed significant decreases in surface runoff for the compost-amended test plots, compared to the soil-only test plots. In fact, very little surface runoff was observed at the Timbercrest compost-amended test plot while the soil-only plot at Timbercrest had an average Rv of only about 0.04. Therefore, the improved infiltration improvement at Timbercrest is not very important from a flow perspective but could be from a mass pollutant runoff perspective. However, the Woodmoor site showed large and important improvements in infiltration conditions, with the Rv being reduced from about 0.25 (relatively large for a soil), to a much smaller Rv of about 0.05.

In addition, the evapotranspiration rates increased with all compost-amended soils, although by only a very small amount at one of the CUH test plot pairs. The increase in evapotranspiration ranged from about 33 to 100% at the newer sites at Timbercrest and Woodmoor.

Table 4-3. Water flow fractions (range and flow-weighted averages)

Location	Treatment	Surface runoff	Subsurface flow	Evapotranspiration
CUH plot 1	Alderwood soil A	0.004 – 0.011 (0.009)	0.50 – 1.00 (0.74)	0.00 – 0.49 (0.25)
CUH plot 2	Alderwood soil A and Cedar Grove compost	0.005 – 0.010 (0.009)	0.45 – 0.89 (0.74)	0.11 – 0.54 (0.25)
	Ratio of compost to soil average fraction	0.98	1.00	1.01
CUH plot 5	Alderwood soil B	0.15 – 0.26 (0.22)	0.39 – 0.83 (0.59)	0.02 – 0.44 (0.19)
CUH plot 6	Alderwood soil B and GroCo compost	0.001 – 0.42 (0.25)	0.00 – 0.77 (0.46)	0.13 – 1.00 (0.29)
	Ratio of compost to soil average fraction	1.10	0.78	1.57
Timbercrest	Alderwood soil C	0.006 – 0.13 (0.040)	0.32 – 0.39 (0.35)	0.54 – 0.68 (0.61)
	Alderwood soil C and Cedar Grove compost	0.00 – 0.00 (0.00)	0.02 – 0.43 (0.19)	0.57 – 0.98 (0.81)
	Ratio of compost to soil average fraction	0.00	0.54	1.33
Woodmoor	Alderwood soil D	0.022 – 0.38 (0.25)	0.13 – 0.74 (0.59)	0.00 – 0.84 (0.16)
	Alderwood soil D and Cedar Grove compost	0.00 – 0.092 (0.045)	0.03 – 0.79 (0.64)	0.15 – 0.97 (0.31)
	Ratio of compost to soil average fraction	0.18	1.08	1.97

Water Quality Observations at Test Plots

Visual Appeal of Test Sites and Need for Fertilization

All test sites began with bare ground and inorganic fertilizer was applied in equal rates at all test sites. All sites did grow grass, however, it became apparent that it would be very difficult to achieve the same visual appeal even with inorganic fertilizer application to the unamended soil, in comparison to the compost-amended soils.

The compost-amended plots developed a dark green color quickly, and achieved 100% coverage much more rapidly than the unamended plots. The compost-amended turf was lush and no soil could be seen through the grass while the unamended plots had many bare spots with exposed soil. The growth rates of turf were also greater for the amended sites and this continued throughout the duration of the study.

Overall Range of Water Quality Observations in Surface Runoff and Subsurface Flows

Results for each sample and QA/QC are given in Appendix G and J, respectively. The water quality measurement results (averages, number of samples and standard deviations) are summarized in Table 4-4.

It is obvious that there is a very large variation in water quality in the surface runoff and subsurface flow samples. For instance, the average total P (TP) concentration for all samples analyzed was 2.76 mg/L, while the minimum P was 0.00 and the maximum 125 mg/L. This high degree of variation in concentration is not unexpected, considering the variety of sampling conditions: test plots with treatments ranging from surface runoff with high water flow in a very infertile, unfertilized glacial till soil to surface runoff and subsurface flows in soils freshly fertilized with soluble NPK fertilizers.

The sampling scheme was organized with a complete block design in order to recognize significant differences between the test plots and between surface runoff and subsurface flows. The following subsection presents the statistical analyses for these comparisons. Before those results are presented, it is worthwhile to examine patterns between the water quality constituents. The following discussion therefore presents the results of simple Pearson correlation analyses, cluster analyses, and principal component analyses that were conducted using the complete data set as presented in Appendix G (except for those analyses resulting in mostly non detected observations). SYSTAT, version 8, was used to conduct these statistical tests.

A Pearson correlation matrix compared all data. High correlations by this analysis would imply close and simple relationships between the contrasted parameters. As an example, it would be expected that many of the nutrients would be highly correlated with each other because of their common source (chemical fertilizer). Table 4-5 shows the correlation pairings that had correlation coefficients greater than 0.7, when all of the water quality data were compared.

The correlation of particle sizes was not included in Table 4-5. The Tenth percentile particle size had a correlated pairing with the Fiftieth percentile particle size (0.791) a s did the Ninetieth percentile particle size with the Fiftieth percentile particle size (0.721). Other correlations not included in Table 4.5 are:

- The largest correlation with NO_3 was with Ca at 0.335.
- Cu had many non detected values; the largest correlation with Cu was with toxicity at 0.342.
- The largest correlations with Fe were with Si at 0.532 and Al at 0.530.
- The largest correlations with Zn were with Al at 0.416, Si at 0.392, and with toxicity at 0.349.
- The largest correlations with toxicity were with S at 0.549, Na at 0.539, SO_4 at 0.594, and Cl at 0.551.

Table 4-4a. Species and elemental concentration averages

			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Site	tmt	type	PO4-P	Hydr P	TOT-P	NH4-N	NO2-N	NO3-N	TOT-N	Cl	SO4-S	Al	As	B	Ba	Ca	Cd	Cr
Timbercrest	comp	lower																
Timbercrest	comp	upper	124.8	15.5	125.2	360.0	0.0	1.7	479.4	0.0	223.0	1.3	0.0	0.0	0.2	74.1	0.0	0.0
Timbercrest	no-comp	lower	0.1	0.3	0.5	0.3	0.0	1.6	2.4	2.2	4.0	7.8	0.0	0.0	0.1	23.2	0.0	0.1
Timbercrest	no-comp	upper	0.0	0.1	0.0	0.0	0.0	0.1	1.6	1.4	1.2	2.5	0.0	0.0	0.0	5.1	0.0	0.0
CUH	comp	lower	0.7	0.5	1.0	0.0	0.0	0.5	2.1	1.3	1.0	5.2	0.0	0.1	0.0	18.8	0.0	0.0
CUH	comp	lower	3.1	3.9	3.9	1.3	0.0	15.3	7.1	10.0	2.9	0.3	0.0	0.0	0.0	31.9	0.0	0.0
CUH	comp	upper	0.9	0.8	1.3	1.9	0.0	0.4	3.5	1.6	0.4	0.9	0.0	0.0	0.0	6.0	0.0	0.0
CUH	comp	upper	3.3	3.3	4.4	3.7	0.0	7.1	8.7	10.3	1.7	0.3	0.0	0.0	0.0	10.3	0.0	0.0
CUH	no-comp	lower	0.0	0.6	0.7	0.1	0.0	0.0	1.7	1.6	0.0	1.0	0.0	0.0	0.0	9.5	0.0	0.0
CUH	no-comp	lower	0.5	0.3	0.6	0.4	0.0	3.7	2.0	2.9	0.5	0.3	0.0	0.0	0.0	12.1	0.0	0.0
CUH	no-comp	upper	0.3	0.3	0.5	1.1	0.0	0.5	2.7	1.9	0.6	24.0	0.0	0.0	0.1	5.3	0.0	0.0
CUH	no-comp	upper	1.0	0.9	1.2	0.8	0.0	3.8	3.5	4.9	0.7	3.0	0.0	0.0	0.0	5.4	0.0	0.0
CUH	precip	precip	0.1	0.0	0.1	0.2	0.0	0.1	1.3	1.0	0.4	0.0	0.0	0.0	0.0	0.4	0.0	0.0
Woodmoor	comp	lower	1.8	2.2	2.9	22.5	0.0	0.5	45.7	38.4	18.3	1.4	0.0	0.1	0.1	93.3	0.0	0.1
Woodmoor	comp	upper	1.1	1.9	2.5	10.7	0.0	0.3	20.1	10.6	2.5	1.1	0.0	0.1	0.1	57.2	0.0	0.0
Woodmoor	no-comp	lower	0.1	0.0	0.1	0.3	0.0	0.6	1.6	2.2	1.8	0.6	0.0	0.0	0.0	34.6	0.0	0.0
Woodmoor	no-comp	upper	0.1	0.2	0.4	0.3	0.0	0.0	1.5	1.9	0.8	4.6	0.0	0.0	0.1	31.1	0.0	0.0
Woodmoor	precip	precip	0.0	0.0	0.0	0.2	0.0	0.2	0.4	1.3	0.5	0.0	0.0	0.0	0.0	0.8	0.0	0.0

			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Site	tmt	type	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Zn	Si	Ag
Timbercrest	comp	lower															
Timbercrest	comp	upper	0.0	0.1	361.1	11.2	0.0	0.0	14.0	0.0	125.2	0.0	356.3	0.0	0.1	6.3	0.0
Timbercrest	no-comp	lower	0.0	4.6	6.2	2.8	0.5	0.0	2.0	0.0	0.5	0.0	3.9	0.2	0.0	9.6	0.0
Timbercrest	no-comp	upper	0.0	1.5	2.7	0.9	0.0	0.0	1.7	0.0	0.0	0.0	1.4	0.0	0.0	4.0	0.0
CUH	comp	lower	0.0	4.0	10.6	6.8	0.3	0.0	2.2	0.0	1.0	0.0	2.0	0.2	0.0	17.4	0.0
CUH	comp	lower	0.0	1.4	24.8	6.1	0.3	0.0	4.8	0.0	3.9	0.0	4.1	0.0	0.0	6.9	0.0
CUH	comp	upper	0.0	1.5	3.7	2.2	0.2	0.0	1.5	0.0	1.3	0.0	0.9	0.1	0.0	4.9	0.0
CUH	comp	upper	0.0	0.8	29.2	2.4	0.2	0.0	3.6	0.0	4.4	0.0	2.7	0.0	0.2	1.8	0.0
CUH	no-comp	lower	0.0	1.8	2.6	4.7	0.0	0.0	3.1	0.0	0.7	0.0	0.4	0.1	0.0	10.7	0.0
CUH	no-comp	lower	0.0	0.1	7.3	5.9	0.0	0.0	5.2	0.0	0.6	0.0	0.9	0.1	0.1	7.7	0.0
CUH	no-comp	upper	0.0	5.9	3.5	4.7	0.0	0.0	6.0	0.0	0.6	0.0	0.9	0.3	0.3	55.2	0.0
CUH	no-comp	upper	0.0	0.9	12.9	2.2	0.0	0.0	3.6	0.0	1.2	0.0	1.2	0.1	0.2	9.0	0.0
CUH	precip	precip	0.0	0.1	2.4	0.1	0.0	0.0	0.6	0.0	0.1	0.0	0.5	0.0	0.0	0.1	0.0
Woodmoor	comp	lower	0.0	3.1	131.5	32.4	4.5	0.0	14.1	0.1	2.9	0.0	21.3	0.3	0.0	8.3	0.0
Woodmoor	comp	upper	0.0	2.0	86.2	19.8	1.4	0.0	6.1	0.0	2.5	0.0	4.5	0.2	0.1	6.4	0.0
Woodmoor	no-comp	lower	0.0	4.8	6.1	6.5	1.2	0.0	2.6	0.0	0.1	0.0	2.6	0.1	0.0	8.3	0.0
Woodmoor	no-comp	upper	0.0	8.4	4.0	5.8	2.9	0.0	1.7	0.0	0.4	0.0	1.3	0.2	0.2	11.3	0.0
Woodmoor	precip	precip	0.0	0.0	3.9	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.4	0.0	0.2	0.0	0.0

Table 4-4b. Species and elemental concentration sample numbers

			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Site	tmt	type	PO4-P	Hydr P	TOT-P	NH4-N	NO2-N	NO3-N	TOT-N	Cl	SO4-S	Al	As	B	Ba	Ca	Cd	Cr
Timbercrest	comp	lower																
Timbercrest	comp	upper	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Timbercrest	no-comp	lower	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Timbercrest	no-comp	upper	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2
CUH	comp	lower	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	comp	lower	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	comp	upper	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	comp	upper	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	no-comp	lower	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	no-comp	lower	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
CUH	no-comp	upper	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	no-comp	upper	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	precip	precip	7	7	7	7	7	6	7	7	7	7	7	7	7	7	7	7
Woodmoor	comp	lower	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Woodmoor	comp	upper	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Woodmoor	no-comp	lower	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Woodmoor	no-comp	upper	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Woodmoor	precip	precip	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Site	tmt	type	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Zn	Si	Ag
Timbercrest	comp	lower															
Timbercrest	comp	upper	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Timbercrest	no-comp	lower	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Timbercrest	no-comp	upper	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
CUH	comp	lower	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	comp	lower	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	comp	upper	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	comp	upper	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	no-comp	lower	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	no-comp	lower	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
CUH	no-comp	upper	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	no-comp	upper	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
CUH	precip	precip	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Woodmoor	comp	lower	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Woodmoor	comp	upper	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Woodmoor	no-comp	lower	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Woodmoor	no-comp	upper	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Woodmoor	precip	precip	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 4-4c. Species and elemental concentration standard deviations

			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Site	tmt	type	PO4-P	Hydr P	TOT-P	NH4-N	NO2-N	NO3-N	TOT-N	Cl	SO4-S	Al	As	B	Ba	Ca	Cd	Cr
Timbercrest	comp	lower																
Timbercrest	comp	upper																
Timbercrest	no-comp	lower	0.1	0.1	0.2	0.5	0.0	1.5	1.2	2.1	0.5	6.4	0.0	0.0	0.0	15.3	0.0	0.1
Timbercrest	no-comp	upper	0.0	0.2	0.0	0.0	0.0		0.2	1.3	1.3	0.3	0.0	0.0	0.0	4.9	0.0	0.0
CUH	comp	lower	0.6	0.7	0.9	0.0	0.0	1.1	1.3	1.0	0.9	4.5	0.0	0.1	0.0	4.6	0.0	0.0
CUH	comp	lower	3.1	3.0	3.5	2.0	0.0	26.6	4.9	11.3	4.3	0.6	0.0	0.0	0.0	47.8	0.0	0.0
CUH	comp	upper	0.6	0.8	1.1	2.5	0.0	0.5	3.0	0.8	0.3	0.6	0.0	0.1	0.0	8.6	0.0	0.0
CUH	comp	upper	2.4	2.5	3.2	7.0	0.0	5.5	10.7	8.2	1.0	0.7	0.0	0.0	0.0	7.1	0.0	0.0
CUH	no-comp	lower	0.0	1.6	1.7	0.0	0.0	0.0	1.5	0.9	0.0	1.0	0.0	0.0	0.0	4.7	0.0	0.0
CUH	no-comp	lower	0.5	0.4	0.6	0.4	0.0	4.7	1.6	3.4	0.5	0.5	0.0	0.0	0.0	7.1	0.0	0.0
CUH	no-comp	upper	0.3	0.3	0.4	1.6	0.0	0.6	2.5	1.1	0.4	28.2	0.0	0.1	0.1	0.7	0.0	0.0
CUH	no-comp	upper	1.3	1.3	1.5	0.8	0.0	3.8	2.9	4.8	0.4	5.7	0.0	0.0	0.0	2.3	0.0	0.0
CUH	precip	precip	0.1	0.0	0.2	0.2	0.0	0.1	0.7	0.3	0.1	0.0	0.0	0.1	0.0	0.3	0.0	0.0
Woodmoor	comp	lower	1.1	1.7	1.9	27.4	0.0	1.1	54.3	79.8	32.2	2.0	0.0	0.0	0.1	67.1	0.0	0.0
Woodmoor	comp	upper	0.4	1.1	1.2	12.2	0.0	0.5	20.0	7.9	1.8	2.0	0.0	0.0	0.1	8.2	0.0	0.0
Woodmoor	no-comp	lower	0.1	0.0	0.1	0.3	0.0	1.5	0.9	1.5	2.7	0.9	0.0	0.0	0.0	27.7	0.0	0.0
Woodmoor	no-comp	upper	0.1	0.5	0.7	0.4	0.0	0.0	0.7	1.1	1.2	5.8	0.0	0.0	0.0	26.8	0.0	0.0
Woodmoor	precip	precip																

			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Site	tmt	type	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Zn	Si	Ag
Timbercrest	comp	lower															
Timbercrest	comp	upper															
Timbercrest	no-comp	lower	0.0	3.6	3.0	1.6	0.6	0.0	0.4	0.1	0.2	0.0	0.8	0.1	0.1	7.7	0.0
Timbercrest	no-comp	upper	0.0	0.2	2.6	0.5	0.0	0.0	1.6	0.0	0.1	0.0	1.5	0.0	0.0	0.2	0.0
CUH	comp	lower	0.0	1.9	8.1	1.0	0.4	0.0	0.7	0.1	0.9	0.0	1.2	0.1	0.1	8.3	0.0
CUH	comp	lower	0.0	1.8	20.9	5.1	0.8	0.0	5.2	0.0	3.5	0.0	4.6	0.0	0.0	5.8	0.0
CUH	comp	upper	0.0	1.9	0.9	3.0	0.4	0.0	0.9	0.0	1.1	0.0	0.4	0.0	0.1	6.0	0.0
CUH	comp	upper	0.0	1.7	23.8	1.4	0.3	0.0	2.6	0.1	3.2	0.0	1.6	0.0	0.1	1.2	0.0
CUH	no-comp	lower	0.0	2.9	1.2	1.4	0.0	0.0	0.8	0.0	1.7	0.0	0.4	0.0	0.0	3.3	0.0
CUH	no-comp	lower	0.0	0.2	6.2	4.1	0.0	0.0	1.7	0.0	0.6	0.0	0.7	0.0	0.2	5.2	0.0
CUH	no-comp	upper	0.0	6.0	1.0	2.8	0.0	0.0	4.3	0.1	0.3	0.0	0.7	0.3	0.2	65.6	0.0
CUH	no-comp	upper	0.0	1.4	11.1	0.7	0.0	0.0	2.2	0.0	1.5	0.0	0.5	0.1	0.1	13.5	0.0
CUH	precip	precip	0.0	0.1	1.8	0.1	0.0	0.0	0.2	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0
Woodmoor	comp	lower	0.0	3.1	122.5	26.2	5.6	0.0	14.9	0.1	1.9	0.0	27.4	0.3	0.0	4.1	0.0
Woodmoor	comp	upper	0.0	2.2	53.4	4.6	1.5	0.0	3.1	0.0	1.2	0.0	2.1	0.1	0.2	3.2	0.0
Woodmoor	no-comp	lower	0.0	6.7	4.4	5.0	1.9	0.0	1.4	0.0	0.1	0.0	3.1	0.1	0.1	6.0	0.0
Woodmoor	no-comp	upper	0.0	9.4	2.8	4.8	3.9	0.0	0.7	0.0	0.7	0.0	1.5	0.1	0.4	3.0	0.0
Woodmoor	precip	precip															

Table 4-5. Observed data correlations exceeding 0.7

Correlation with	PO_4	TP	NH_4	TN	Cl	SO_4	Al	Ca	K	Mg	Mn	Na	S	Si
PO_4	X	0.998	0.975	0.955	---	0.949	---	---	---	---	---	---	0.981	---
TP	0.998	X	0.976	0.958	---	0.945	---	---	---	---	---	---	0.979	---
NH_4	0.975	0.976	X	0.995	---	0.977	---	---	0.773	---	---	---	0.994	---
TN	0.955	0.958	0.995	X	---	0.978	---	---	0.828	---	---	---	0.987	---
Cl	---	---	---	---	X	---	---	---	---	0.699	---	0.723	---	---
SO_4	0.949	0.945	0.977	0.978	---	X	---	---	0.774	---	---	---	0.998	---
Al	---	---	---	---	---	---	X	---	---	---	---	---	---	0.964
Ca	---	---	---	---	---	---	---	X	---	0.901	0.758	0.739	---	---
K	---	---	0.773	0.828	---	0.774	---	---	X	---	---	---	---	---
Mg	---	---	---	---	0.699	---	---	0.901	---	X	---	0.810	---	---
Mn	---	---	---	---		---	---	0.758	---	---	X	---	---	---
Na	---	---	---	---	0.723	---	---	0.739	---	0.810	---	X	---	---
S	0.981	0.979	0.994	0.987	---	0.988	---	---	---	---	---	---	X	---
Si	---	---	---	---	---	---	0.964	---	---	---	---	---	---	X

These correlation coefficients of Table 4-5 show the expected strong correlations between the nutrient parameters and between other obviously related parameters (such as SO_4 and S, major cations and major anions, and particle sizes). It is surprisingly to note the poor correlation between NO_3 and TN (0.011) and between NO_3 and NH_4 (0.002). The strongest correlations with toxicity were for salinity parameters (NaCl and SO_4), pointing out the sensitivity of the test organism (a marine phytobacterium) with salinity.

More complex inter-relationships between the chemical parameters can be identified through cluster analyses. Figure 4-1 is a dendogram showing the close relationships between the nutrients, and less clear relationships for many of the other parameters. Phosphate and total phosphorus, along with ammonium and total nitrogen, have the closest and simplest relationships, while nitrate is poorly related to any other parameter. The major cations and major anions have a somewhat more complex inter-relationship, while toxicity was affected by all of the major ions, plus the nutrients.

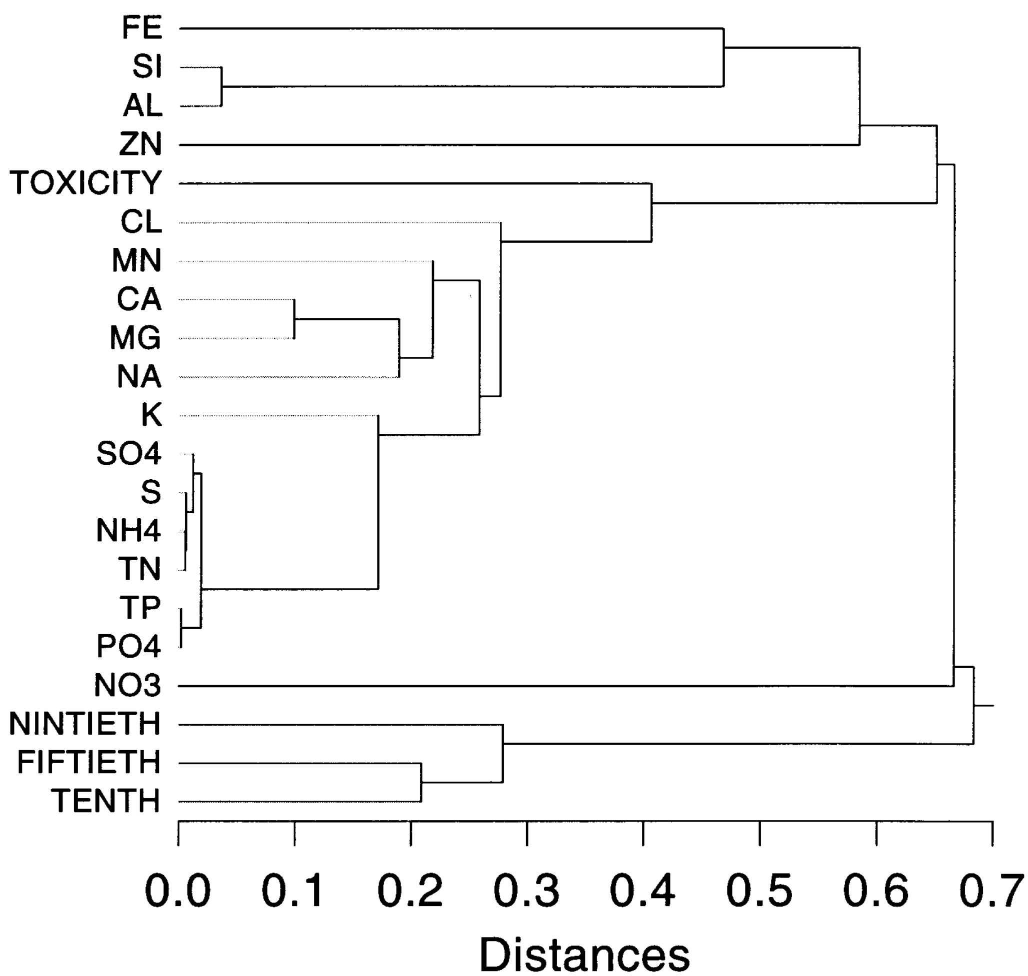

Figure 4-1. Dendogram showing complex relationships of monitored chemical parameters at soil and amended soil test sites.

A principal component evaluation of all of the water quality parameters was conducted. This analysis also groups the parameters into components that are closely related. In this case, three components accounted for about 75% of the total variance of the data. The first component accounted for about 45% of the variance and is mostly associated with the following 11 parameters: NH_4, TN, Cl, SO_4, Ca, K, Mg, Mn, Na, S, and toxicity. This component is mostly made of the major cations and anions, plus the nitrogen compounds, and toxicity. The second most important component explained a further 18% of the variance and is mostly associated with the following six parameters: Al, Fe, Si, and the three particle size parameters. The final principal component explained about 12% of the total variance and is comprised of the following four parameters: PO_4, TP, NO_3, and Zn. Less important components accounted for the remaining 25% of the total variance and were comprised of combinations of all of the water quality parameters.

Appendix I summarizes some water quality criteria and goals and is presented as a general reference for comparison to the measured water quality at the test sites. The following briefly lists some of these criteria and goals for the water quality constituents measured during this study:

Phosphate	0.1 mg/L goal to prevent eutrophication in flowing waters
Ammonia	as low as 0.11 mg/L for warm water and pH of 9, to 2.5 mg/L for cold water and pH of 6.5
Nitrate	10 mg/L for human health
Chloride	250 mg/L for human health
Zinc	5 mg/L (human health, through consumption of fish)
	33 at 25 mg/L hardness to 140 mg/L at 140 mg/L hardness for chronic exposure to fish

Many of the observed phosphate and ammonia concentrations exceeded the above water quality goals during all test conditions. However, only the maximum observed nitrate values exceeded the nitrate standard, and no chloride or zinc observations exceeded any of the listed criteria.

The average soluble-reactive P (PO_4-P) concentration for all analyzed samples was 2.3 mg/L, while the minimum P was below detection, and the maximum was 125 mg/L. The average PO_4-P concentration measured is considerably above the State of Washington Water Quality recommendations for freshwater, according to WAC 173-201 (1992), which is 0.1 mg/L for flowing water not discharging directly into a lake or impoundment. The ammonium-N concentration averaged 6.6 mg/L, while the minimum ammonium-N was below detection, and the maximum was 360 mg/L. The NO_3-N concentration averaged 2.6 mg/L, while the minimum NO_3-N was below detection, and the maximum was 74 mg/L.

Overall, 72% of the 63 samples analyzed were not toxic (<20% light reductions), 25% were moderately toxic (light reductions of 20 to 60%), and 3% (2 samples) were highly toxic (>60% light reductions). The toxic samples from the Woodmoor test sites were a surface runoff sample from the soil-only plot (2/20/98), and a subsurface flow sample from the compost-amended soil plot (1/5/98).

A few samples had significantly larger concentrations than most of the others, as listed below. These noted constituent concentrations were all much larger than for the other samples (typically at least 10 times greater):

- Woodmoor, Cedar Grove compost-amended test plot:

  1/5/98, the first sample collected from this test plot, subsurface flow sample only (no surface runoff sample was available for analysis): NH_4 (59.4 mg/L), TN (118 mg/L), Cl (181 mg/L), Ca (190 mg/L), K (283 mg/L), Mg (70 mg/L), Mn (13 mg/L), Na (36 mg/L), and S (65 mg/L).

  2/20/98, the next sample after the above analyses (surface runoff, subsurface flow concentrations): NH_4 (27, 43.9 mg/L), TN (48, 90 mg/L), SO_4 (4.8, 11 mg/L), Ca (52, 132 mg/L), and K (158, 241 mg/L).

  3/15/98, the next sample after the above analyses (surface runoff only, as no subsurface flow sample was available for analysis): NH_4 (19 mg/L), TN (34 mg/L), and K (117 mg/L).

• Timbercrest, Cedar Grove compost-amended test plot:
6/26/98, surface runoff sample only (the subsurface sample was not available for analysis): PO_4 (125 mg/L), TP (125 mg/L), NH_4 (360 mg/L), TN (479 mg/L), SO_4 (223 mg/L), K (361 mg/L), and S (356 mg/L).

Water draining from the compost amended Woodmoor site was strongly influenced by the initial Cedar Grove compost amendment which leached nutrients and other minerals. The compost-amended plot showed dramatic decreases in concentrations with time, as shown on Figures 4-2 and 4-3. These figures show decreasing concentrations with time for phosphorus and nitrogen compounds in the subsurface flows for the compost-amended Woodmoor test plot. No noticeable concentration trends are seen for the soil-only test plots. The nitrogen compounds in the subsurface flow from the compost-amended plot approached the subsurface flow concentrations from the soil-only plot after about six months. However, the phosphorus compounds remained high at the end of this period, although the concentrations decreased substantially from the beginning of the test period. As shown in the following subsections, the phosphorus concentrations in the runoff from the compost-amended test plots at the CUH test plots remained two to three times higher than from the soil-only test plots, even after several years.

Both surface runoff and subsurface flows were very high on 2/20/98 at the Woodmoor Cedar Grove compost-amended test plot. That set of analyses showed large increases (about doubling the concentrations) in constituent concentrations after infiltrating through the compost-amended soil. The one very high value at Timbercrest (6/26/98) was also at the compost-amended test plot, but data was only available for the surface runoff. Therefore, it could not be confirmed if the surface runoff was also high, or if earlier samples were even higher (expected).

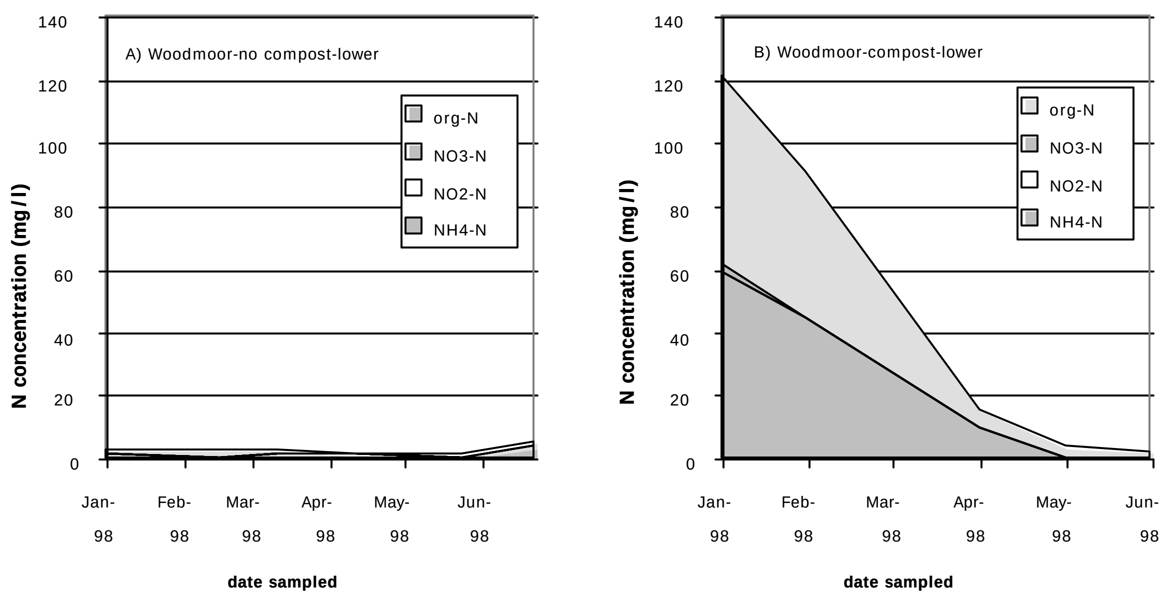

Figure 4-2. Species and elemental concentration averages in subsurface flows (nitrogen).

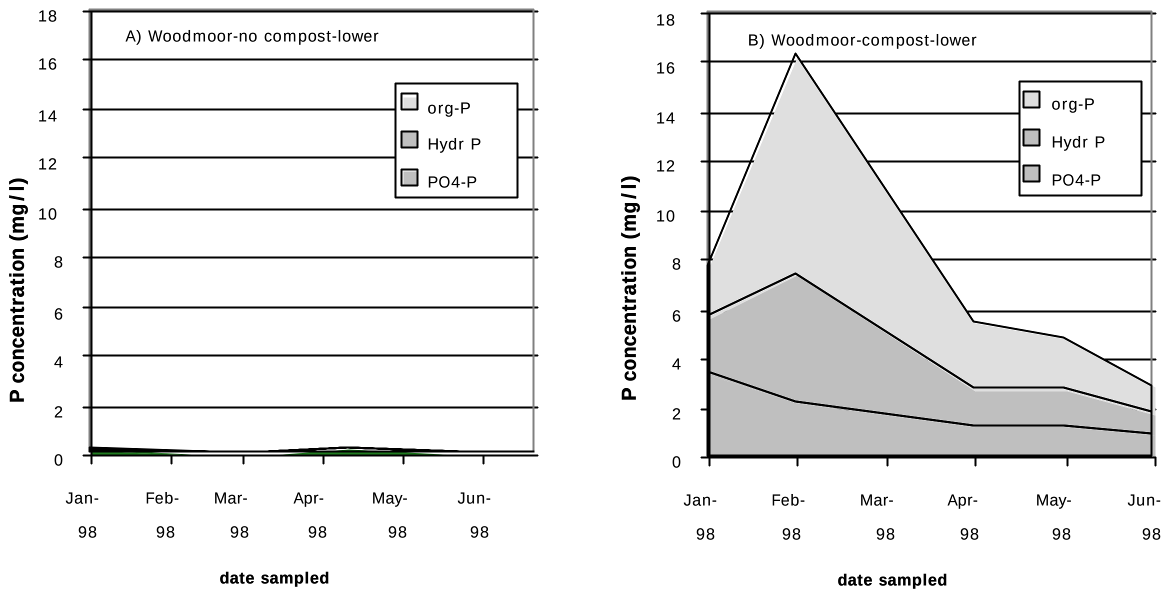

Figure 4-3. Species and elemental concentration averages in subsurface flows (phosphorus).

Comparison of Water Quality from Amended vs. Unamended Test Plots

Table 4-6 summarizes the average concentrations of constituents for surface runoff and subsurface flow samples separated by "soil-only" test plots and "soil plus compost" test plots. This table shows the average observations along with the coefficient of variations (standard deviation divided by the average value). The table only shows data for tests having both surface runoff and subsurface flow samples. The subsurface flows in the soil-only test plots mostly had lower concentrations of constituents than the associated surface runoff. The exceptions (NO_3, SO_4, Ca, Mg, and S) had slightly elevated concentrations (increases of about 10 to 30%) in the subsurface flows in comparison to the surface runoff. However, there were more constituents that were in higher concentrations in subsurface flows, compared to surface runoff, for the compost-amended soil test plots. In addition, the increases were generally larger (as much as 2.5 times greater) than for the increases observed at the soil-only test plots. The constituents with elevated concentrations in the subsurface flows compared to surface runoff at the compost-amended test plots were NO_3, TN, SO_4, Al, Ca, Fe, K, Mg, Mn, Na, and S.

The surface runoff from the compost-amended soil sites had greater concentrations of almost all constituents, compared to the surface runoff from the soil-only test sites. Interestingly, the only exceptions were for the cations Al, Fe, Mn, Zn, and Si, plus toxicity, which were all lower in the surface runoff from the compost-amended soil test sites. The increased concentrations in the surface runoff and subsurface flows from the compost-amended soil test site as compared to the soil-only site were quite large, typically in the range of 5 to 10 times greater. The exceptions were Fe, Zn, and toxicity. Toxicity tests indicated reduced toxicity with filtration at both the soil-only and at the compost-amended test sites.

Figures G-1 through G-29 are the particle size distributions for the analyzed samples. The particle size distributions remained about the same for all test conditions with slightly larger particles for the compost-amended soil test sites.

Statistical tests determined the significance of the differences noted above. Tables G-3 and G-4 (in Appendix G) summarize the surface runoff and subsurface flow quality for different categories of samples for most of the analyses (excluding those that were not detected in the majority of the samples). The analyses included on these tables are:

- nutrients (PO_4, total P, NH_4, NO_3, and total N)
- major ions (Cl, SO_4, Ca, K, Fe, Mg, Mn, Na, Si, and S)
- heavy metals (Al, Cu, and Zn)
- particle sizes (10^{th}, 50^{th}, and 90^{th} percentile sizes, by volume)
- toxicity (percent light decrease using Microtox®)

Table 4-6. Average (and COV) values for all runoff and subsurface flow samples

Constituent (mg/L, unless noted)	Soil-only Plots		Soil plus Compost Plots	
	Surface Runoff	Subsurface Flows	Surface Runoff	Subsurface Flows
PO_4-P	0.27 (1.4)	0.17 (2.0)	1.9 (1.0)	1.8 (1.2)
TP	0.49 (1.0)	0.48 (2.2)	2.7 (0.9)	2.5 (1.1)
NH_4-N	0.65 (1.7)	0.23 (1.3)	4.1 (1.8)	3.5 (3.0)
NO_3-N	0.96 (1.4)	1.2 (2.5)	3.0 (1.6)	6.2 (2.8)
TN	2.5 (0.9)	1.9 (0.7)	8.4 (1.5)	10 (2.1)
Cl	2.4 (1.0)	2.1 (0.9)	6.7 (1.1)	5.0 (1.6)
SO_4-S	0.68 (1.1)	0.95 (2.0)	1.5 (0.9)	2.4 (1.4)
Al	11 (1.8)	1.7 (2.1)	0.7 (1.6)	2.4 (1.6)
Ca	12 (1.5)	17 (0.7)	18 (1.1)	35 (1.1)
Cu	0.01 (0.8)	0.01 (1.6)	0.02 (1.2)	0.02 (0.9)
Fe	4.6 (1.4)	2.8 (1.6)	1.2 (1.5)	2.6 (0.9)
K	5.4 (1.0)	4.6 (0.8)	30 (1.3)	34 (1.6)
Mg	3.9 (0.8)	5.0 (0.6)	5.8 (1.2)	10 (1.1)
Mn	0.75 (2.9)	0.41 (2.8)	0.36 (1.9)	0.80 (2.4)
Na	3.8 (0.9)	3.4 (0.5)	3.2 (0.8)	4.6 (1.2)
S	1.1 (0.8)	1.3 (1.5)	2.5 (0.8)	4.7 (1.6)
Zn	0.2 (1.2)	0.05 (2.2)	0.14 (1.1)	0.03 (1.8)
Si	26 (1.7)	8.9 (0.5)	4.2 (1.1)	11 (0.7)
10^{th} percentile size (μm)	2.9 (0.7)	3.1 (0.4)	2.8 (0.3)	3.5 (0.6)
50^{th} percentile size (μm)	12 (1.0)	13 (0.6)	15 (0.4)	14 (0.7)
90^{th} percentile size (μm)	45 (0.5)	41 (0.5)	46 (0.4)	47 (0.6)
Toxicity (% light decrease)	25 (0.7)	13 (0.5)	16 (0.8)	10 (1.1)

The data in these tables are only for paired analyses, where both surface runoff and subsurface flow samples were analyzed (except for rainfall). Table G-3 compares surface runoff and subsurface flow quality at each test site using the non-parametric Kurskall-Wallis test. The 14 categories examined are shown in Table 4-7 (group 1 compared to group 2, group 3 compared to group 4, etc.):

Table 4-7. Categories examined

Group	Sample type	Treatment	Location	Number of Samples in Group
1	Surface runoff	Alderwood, soil C	Timbercrest	2
2	Subsurface flow	Alderwood, soil C	Timbercrest	2
3	Surface runoff	Alderwood, soil A	CUH	7
4	Subsurface flow	Alderwood, soil A	CUH	7
5	Surface runoff	Alderwood, soil A and CG compost	CUH	7
6	Subsurface flow	Alderwood, soil A and CG compost	CUH	7
7	Surface runoff	Alderwood, soil B	CUH	6
8	Subsurface flow	Alderwood, soil B	CUH	6
9	Surface runoff	Alderwood, soil B and GroCo compost	CUH	7
10	Subsurface flow	Alderwood, soil B and GroCo compost	CUH	7
11	Surface runoff	Alderwood, soil D	Woodmoor	5
12	Subsurface flow	Alderwood, soil D	Woodmoor	5
13	Surface runoff	Alderwood, soil D and CG compost	Woodmoor	4
14	Subsurface flow	Alderwood, soil D and CG compost	Woodmoor	4

Similarly, Table G-4 summarizes the same water quality constituents and compares all surface runoff at composite-amended sites vs. non-amended sites, and also subsurface flows at all compost-amended sites vs. non-amended sites.

Few significant differences were noted in Table G-3 because of the relatively small number of samples in each of the many different categories. The following list shows the comparisons that had probabilities of being the same in each of the two data sets being compared with values of 0.1 or less (" $\leq$ 0.1). These comparisons examined surface runoff vs. subsurface flow water quality (with the ratio of average subsurface flow to surface runoff concentrations shown in parentheses):

CUH (Alderwood soil A only)

- PO_4 (0.54)
- TP (0.40)
- NH_4 (0.19)
- SO_4 (0.38)
- Al (0.04)
- Ca (1.6)
- Fe (0.08)
- Na (0.56)
- S (0.43)
- Zn (0.23)
- 10^{th} (1.51)
- toxicity (0.54)

CUH (Alderwood soil A and Cedar Grove compost)

- NH_4 (0.05)
- Al (11.3)
- Ca (4.4)
- Cu (2.5)
- Fe (9.6)
- Mg (4.6)
- Na (1.6)
- Zn (0.06)
- Si (11.7)
- toxicity (0.46)

CUH (Alderwood soil B only)

- SO4 (0.63)
- Ca (2.7)
- Mg (2.4)
- Na (2.0)
- Zn (0.13)
- Si (2.1)

CUH (Alderwood soil B and GroCo compost)

- none

Timbercrest (Alderwood soil C only)

- none

Woodmoor (Alderwood soil D only)

- Si (0.56)

Woodmoor (Alderwood soil D and Cedar Grove compost)

- Cl (0.3)

The following lists a similar summary of the significant differences shown on Table G-4. These comparisons contrasted water quality at all soil-only sites and at composted-amended sites for surface runoff and subsurface flows separately (the ratios of compost-amended site data to soil-only site data are shown in parentheses):

Surface Runoff

- PO_4 (6.9)
- TP (5.6)
- TN (3.4)
- SO_4 (2.2)
- Al (0.07)
- Cu (3.6)
- Fe (0.26)
- K (5.6)
- S (2.3)
- Si (0.16)

Subsurface Flows

- PO_4 (10.5)
- TP (5.3)
- TN (5.2)
- SO_4 (2.5)
- Ca (2.1)
- Cu (4.1)
- K (7.4)
- Mg (2.0)
- S (3.5)

Mass Discharges of Nutrients and other Water Quality Constituents

The mass discharges of water and nutrients were calculated for each sampling period. As noted previously, compost-amended soils increased concentrations of many constituents in the surface runoff. However, the compost amendments also significantly decreased the amount of surface runoff leaving the test plots, at least for a few years. Table 4-8 summarizes these expected changes in surface runoff and subsurface flow mass pollutant discharges associated with compost-amended soils, using the paired data only. The concentration increases were multiplied by the runoff reduction factors to obtain these relative mass discharge changes. The decreases in runoff volume were for the newer test sites. The older test sites had less dramatic reductions in runoff values. The older sites also had smaller concentration increases associated with the addition of compost to the soil. All of the surface runoff mass discharges are reduced by large amounts (2 to 50 percent of the unamended discharges). However, many of the subsurface flow mass discharges are expected to increase, especially for ammonia (340% increase), phosphate (200% increase), plus total phosphorus, nitrates, and total nitrogen (all with 50% increases). Most of the other constituent mass discharges in the amended plot subsurface flows are expected to decrease.

The compost has significant sorption capacity and ion exchange capacity that is responsible for pollutant reductions in the infiltrating water. However, the compost also leaches large amounts of nutrients to the surface and subsurface waters.

Table 4-8. Changes in Pollutant Discharges from Surface Runoff and Subsurface Flows at New Compost-Amended Sites, Compared to Soil-Only Sites

Constituent	Surface Runoff Discharges, Amended-Soil Compared to Unamended Soil (ratio)	Subsurface Flow Discharges, Amended-Soil Compared to Unamended Soil (ratio)
Runoff Volume	0.09	0.29
Phosphate	0.62	3.0
Total phosphorus	0.50	1.5
Ammonium nitrogen	0.56	4.4
Nitrate nitrogen	0.28	1.5
Total nitrogen	0.31	1.5
Chloride	0.25	0.67
Sulfate	0.20	0.73
Calcium	0.14	0.61
Potassium	0.50	2.2
Magnesium	0.13	0.58
Manganese	0.042	0.57
Sodium	0.077	0.40
Sulfur	0.21	1.0
Silica	0.014	0.37
Aluminum	0.006	0.40
Copper	0.33	1.2
Iron	0.023	0.27
Zinc	0.061	0.18

Since Table 4-8 was based on paired analyses only (requiring both surface runoff and subsurface flow data for the calculations), the values may over-predict the benefits of compost-amended soils. The analysis did not include the three samples with very high concentration, as these samples did not have the appropriate paired data for comparison/confirmation. On the other hand, the mass discharge calculations shown in Appendix H are likely overly conservative because the few extremely high values greatly distort the averaged values used in the calculations.